AD-A279 067

REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
December 1989

3. REPORT TYPE AND DATES COVERED
Technical Oct 1989 - Dec 1989

4. TITLE AND SUBTITLE
A Mesh Generator for Finite Element Structural Analysis in Two Dimensions

5. FUNDING NUMBERS
C

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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8. PERFORMING ORGANIZATION REPORT NUMBER
SPC 89-1465-12

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Defense Advanced Research Projects Agency
1400 Wilson Blvd
Arlington, Virginia 22209

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Contract No. F2960-86-C-0026

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

Finite element structural analysis is gaining wide acceptance in the field of projectile design. In the past, computer memory and storage requirements have limited the application of finite element analysis to large main frame computers and workstations. Recently, great improvements have been made in the computing power of desk top personal computers. As a result, interest has developed in applying finite element software to the P.C. environment. The mathematics and computer algorithms for finite element analysis are readily obtained from engineering references. However, the most tedious and time consuming operation is the generation of the finite element model. A suitable mesh generator is, therefore, required to fully implement any finite element package on a personal computer. This report presents a straight-forward and easy to implement two-dimensional mesh generator for both plane strain and axisymmetric analysis. Computer code listing and examples are provided.

14. SUBJECT TERMS
mesh generator, finite element analysis, projectiles, personal computer, FORTRAN

15. NUMBER OF PAGES
39

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

SPC 89-1465-12

A MESH GENERATOR FOR FINITE ELEMENT STRUCTURAL ANALYSIS IN TWO DIMENSIONS

DECEMBER 1989

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94-14255

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1. BACKGROUND

Finite element structural analysis is gaining wide acceptance in the field of projectile design. In the past, computer memory and storage requirements have limited the application of finite element analysis to large main frame computers and workstations. Recently, great improvements have been made in the computing power of desk top personal computers. As a result, interest has developed in applying finite element software to the P.C environment. The mathematics and computer algorithms for finite element analysis, in particular the extensive matrix operations required to solve the stiffness and deformation of the structure, have existed for many years, and are readily obtained from engineering references. However, the most tedious and time consuming operation is the generation of the finite element model. A suitable mesh generator is, therefore, required to fully implement any finite element package on a personal computer. This report presents an approach to developing the two-dimension finite element grid. The computer code listing is provided in the appendix, along with an example mesh generation. The documentation is sufficiently detailed to permit the programmer to tailor the mesh generation software to suit particular finite element analysis requirements.

2. MESH GENERATOR REQUIREMENTS

Advanced projectile structural design typically involves the analysis of complicated projectile shapes, such as the sabot, shown in cross-section, in Figure 2.1 Figure 2.2 shows a generic long rod penetrator within this structural sabot. This type of projectile configuration is typically used in kinetic energy anti-tank projectiles. The cross-section drawing shown in Figure 2.2 is created using a generic solids modeling algorithm. Table 2.1 shows the structural dimensions defining this generic projectile.

Table 2.1
Projectile Geometric Inputs

```
*
SABOT
2.0
   8   4
1.0000
 ELEM    D1        D2        L         Rho    FORM    R         H         K
   1    1.3       2.0       2.25               3
   2    2.0       2.5       0.25               43    0.5       0.2057    1.4557
   3    3.0       3.0       1.0                2
   4    2.5       2.0       0.25               44    0.5       0.2057    1.4557
   5    2.0       1.4       2.25               3
   6    1.4       1.65      0.5                43    1.0       0.0157    1.70
   7    1.65      3.0       1.0                3
   8    3.0       3.0       0.5                2
   9    1.0       1.0       6.5                2
  10    1.0       1.5       0.25               42    .5        0.2057    -0.2943
  11    1.5       2.7       0.85               3
  12    2.7       2.7       0.40               2
*
PEN
0.0
   1   0
6.6400
 ELEM    D1        D2        L         Rho    FORM    R         H         K
   1    1.0       1.0       10.5               2
**
```

Figure 2.1
Cross-Section of a Generic Projectile Sabot

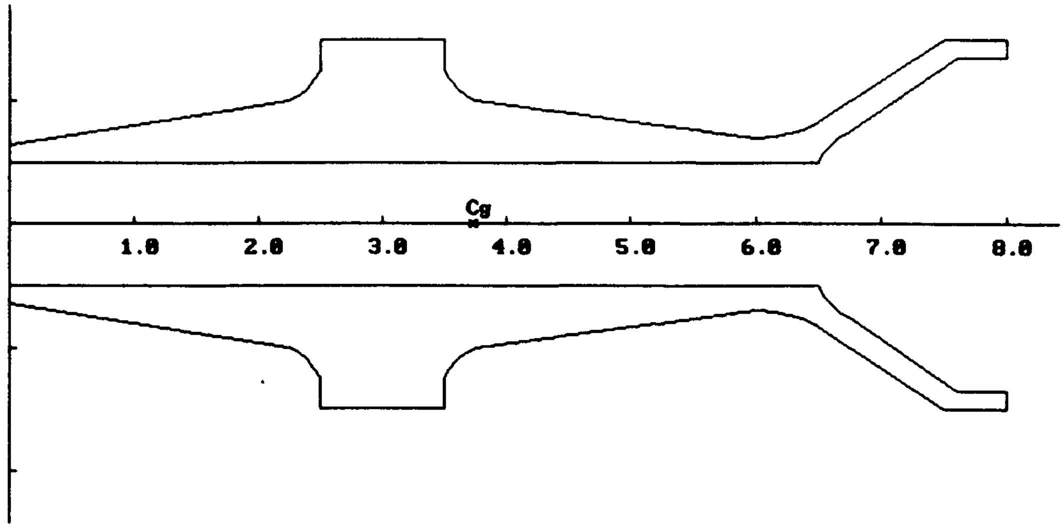
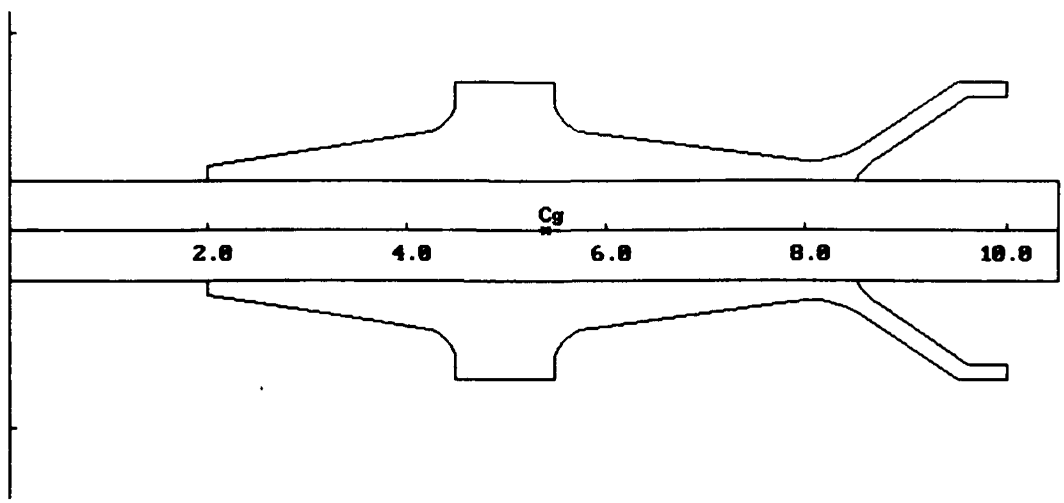


Figure 2.2
Cross-Section of Generic Kinetic Energy Projectile

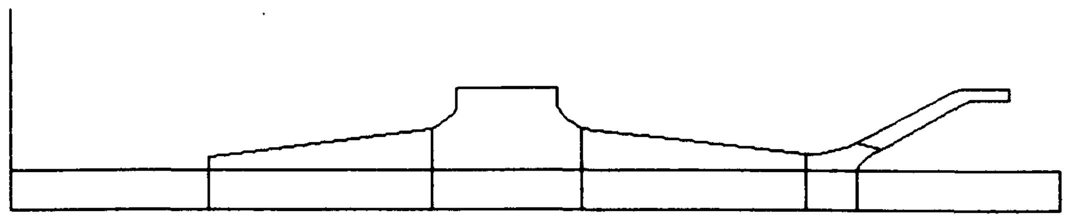


What is desired is to create a finite element grid within the boundaries of this projectile form. Finite element analysis typically requires the structure to be divided into individual quadrilateral elements. By convention, each element is defined by four corner nodes, in either a clock-wise or counter clock-wise direction, depending on the finite element algorithm. To ensure that all of the elements are structurally connected, adjacent elements are defined by common node numbers, depending on their location in the assembled grid. A file structure is then developed which allows the finite element analysis program to create the stiffness matrix, based on the element corner nodes and the x and y or z and r coordinates of each node.

3. CREATING THE FINITE ELEMENT GRID

The mesh generator algorithm presented in this report follows a systematic process to creating the finite element grid. First the projectile form is subdivided into homogenous areas, by defining area corner points and lines, based on the modeler's vision of how the grid is to be developed. Figure 3.0 shows an outline of the structure, when broken into sub-areas for grid generation. Figure 3.1 shows 32 discrete points defining the boundary of this structure. Table 3.1 shows the input format for these 32 points, as required by the software. Four additional points are entered in this example, which are not corner points, but are required for complete description of the geometry. The structure in Figure 2.2 includes four radii, which describe the curvature of the outline at the base of the central bulkhead and the root of the front scoop. For each radius in the structure, the center point of the curvature also needs to be defined. Therefore, points 12, 15, 22, and 26 are the centers for these curves. Each point input defines the point number, followed by its x and y position for a two-dimension plane strain model, or its z and r position, if the model is axisymmetric. For this example, the projectile is an axisymmetric structure, so the coordinates are in terms of the longitudinal position and the radial position of the point.

Figure 3.0
Geometry Sub-Area Definitions



Following the corner point definitions, the perimeter lines for each of the sub-areas are defined. Table 3.2 gives the line inputs for this example, and Figure 3.2 shows the line definitions graphically. Each line input defines the line number, followed by the two line end points, the number of finite divisions for this line, and the center point if the line is a radius. When defining the lines, as when defining the sub-areas and their corner points, the modeler needs to have a scheme in mind for how the mesh is to be generated. Line divisions should be consistent for opposite sides of each sub-area, so that a consistent quadrilateral grid will be generated. In addition, the line divisions for adjacent areas should be consistent so that the entire structure can be merged together.

Table 3.1
Sub-Area Corner Point Inputs

```
P,1,0,0.0
P,2,0,0.5
P,3,2.0,0.0
P,4,2.0,0.5
P,5,4.25,0.0
P,6,4.25,0.5
P,7,4.25,1.0
P,8,2.0,0.65
P,9,5.75,0.0
P,10,5.75,0.5
P,11,4.5,1.25
P,12,4.0443,1.4557
P,13,4.5,1.5
P,14,5.5,1.5
P,15,5.9557,1.4557
P,16,5.5,1.25
P,17,5.75,1.0
P,18,8.0,0.0
P,19,8.0,0.5
P,20,8.0,0.7
P,21,8.5,0.825
P,22,8.0000,1.7
P,23,8.5,0.0
P,24,8.5,0.5
P,25,8.75,0.75
P,26,8.9557,0.2943
P,27,9.6,1.35
P,28,9.5,1.5
P,29,10.0,1.35
P,30,10.0,1.5
P,31,10.5,0.0
P,32,10.5,0.5
```

Figure 3.1
Points Defining the Sub-Areas of the Structure

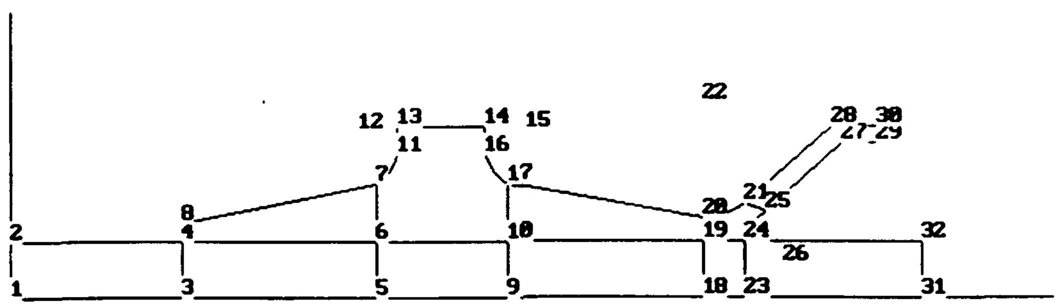


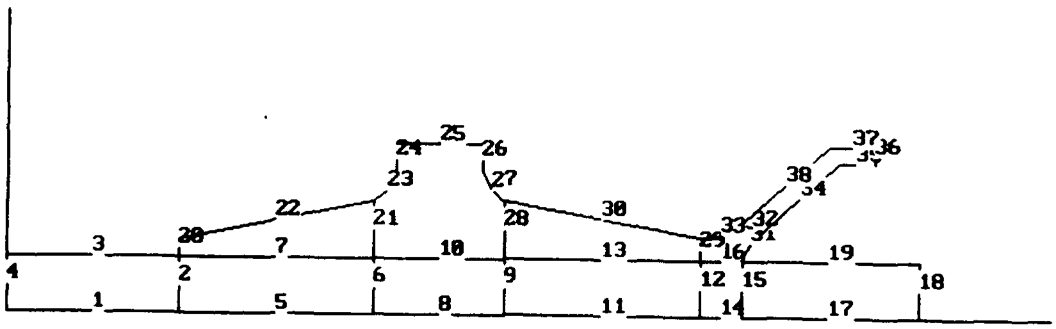
Table 3.2

Sub-Area Line Inputs

```
L,1,1,3,5,,
L,2,3,4,5,,
L,3,4,2,5,,
L,4,1,2,5,,
L,5,3,5,20,,
L,6,5,6,5,,
L,7,6,4,20,,
L,8,5,9,20,,
L,9,9,10,5,,
L,10,10,6,20,,
L,11,9,18,20,,
L,12,18,19,5,,
L,13,19,10,20,,
L,14,18,23,8,,
L,15,23,24,5,,
L,16,24,19,8,,
L,17,23,31,4,,
L,18,31,32,5,,
L,19,32,24,4,,
L,20,4,8,5,,
L,21,6,7,5,,
L,22,7,8,20,,
L,23,7,11,4,12
L,24,11,13,3,,
L,25,13,14,20,,
L,26,14,16,3,,
L,27,16,17,4,15
L,28,10,17,5,,
L,29,19,20,5,,
L,30,20,17,20,,
L,31,24,25,5,26
L,32,25,21,3,,
L,33,21,20,5,22
L,34,25,27,10,,
L,35,27,29,3,,
L,36,29,30,3,,
L,37,30,28,3,,
L,38,28,21,10,,
```

Figure 3.2

Lines Defining the Sub-Areas of the Structure



One may have noticed that three of the sub-areas are defined by more than four lines and more than four perimeter points. Since typical structures involve complicated shapes, which are not easily described by four nearly parallel sides, mesh generation requires the use of splines. Splines are groups of lines, which are to be treated as a single line in the mesh generation process. This approach makes mesh generation of complicated shapes easier to accomplish. Table 3.3 shows the five spline inputs for this example. When defining splines, at most five lines can be connected, and they should be listed in the order they appear in the geometry. As with the definition of individual lines, the total number of divisions for a spline should be consistent with the opposite side of the sub-area which it describes.

Table 3.3
Spline Inputs

```
S,1,21,23,24,,,
S,2,28,27,26,,,
S,3,32,33,,,,
S,4,34,35,,,,
S,5,37,38,,,,
```

Following the spline inputs, the model is ready to be meshed with a finite element grid. The mesh commands define each sub-area to be meshed in accordance with the points, lines, and splines described earlier. For each area, the four corner points are entered in either a clock-wise or counter clock-wise direction, depending on the convention used in the finite element software. Table 3.4 shows the area mesh commands used in this example. The command line consists of the area number, followed by the four corner points, followed by the mesh technique (1 or 2), and finally the material number, so that material properties can be discriminated later in the finite element analysis. Two mesh technique numbers were developed in the software, since any one technique is not always the best, depending on the shape of the sub-area. Technique 1 works well for areas which are more square or rectangular, as opposed to areas which include a curved perimeter. Some experimentation is required to develop the best looking grid for a particular sub-area. The algorithm is adequately general to permit the grid to take several forms. Results

will vary depending on the direction and the order used for the area corner points in the mesh command. The modeler needs to decide which results are best for the particular application. Figure 3.3 shows the resulting mesh using the commands in Table 3.4. Figure 3.4 shows a close-up of the mesh in the bulkhead region. Figure 3.5 shows a close-up of the root of the front scoop with a point and line plot. Figure 3.6 is the resulting mesh for the front scoop. The mesh generation for both of these areas included the use of splines.

Table 3.4
Area Mesh Command Inputs

```
A,1,3,4,2,1,1,1
A,2,3,4,6,5,1,1
A,3,5,9,10,6,1,1
A,4,9,18,19,10,1,1
A,5,18,23,24,19,1,1
A,6,23,31,32,24,1,1
A,7,4,6,7,8,1,2
A,8,6,10,14,13,1,2
A,9,10,19,20,17,1,2
A,10,20,25,24,19,2,2
A,11,29,30,21,25,1,2
*
```

Figure 3.3
The Complete Finite Element Grid

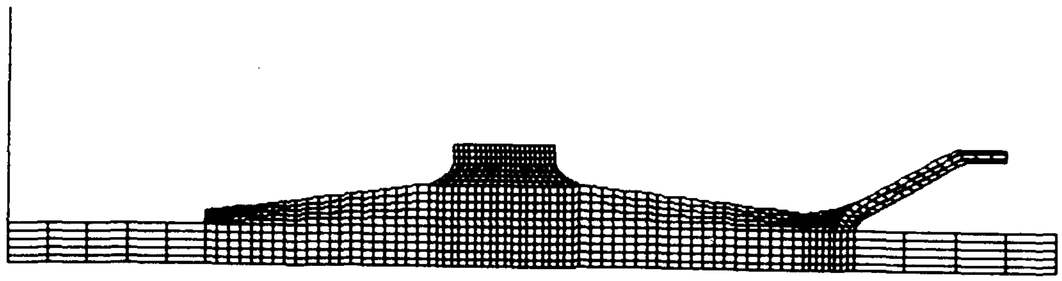


Figure 3.4
Close-Up of the Bulkhead Region Grid

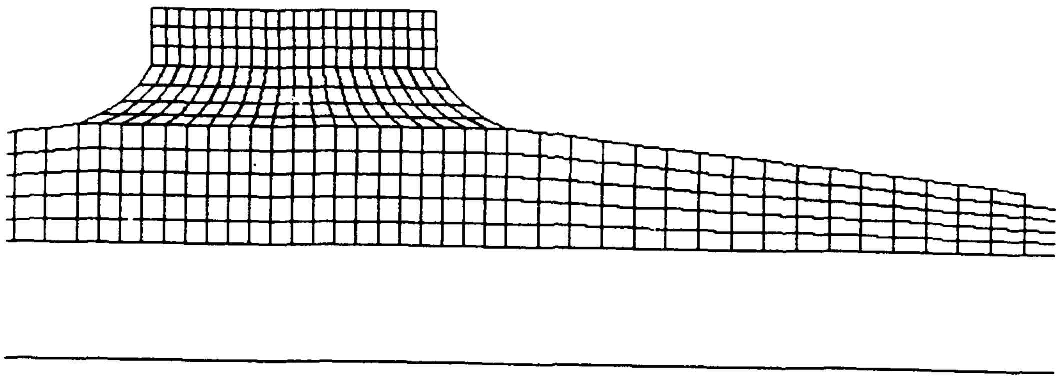


Figure 3.5
Point and Line Plot of the Front Scoop Region

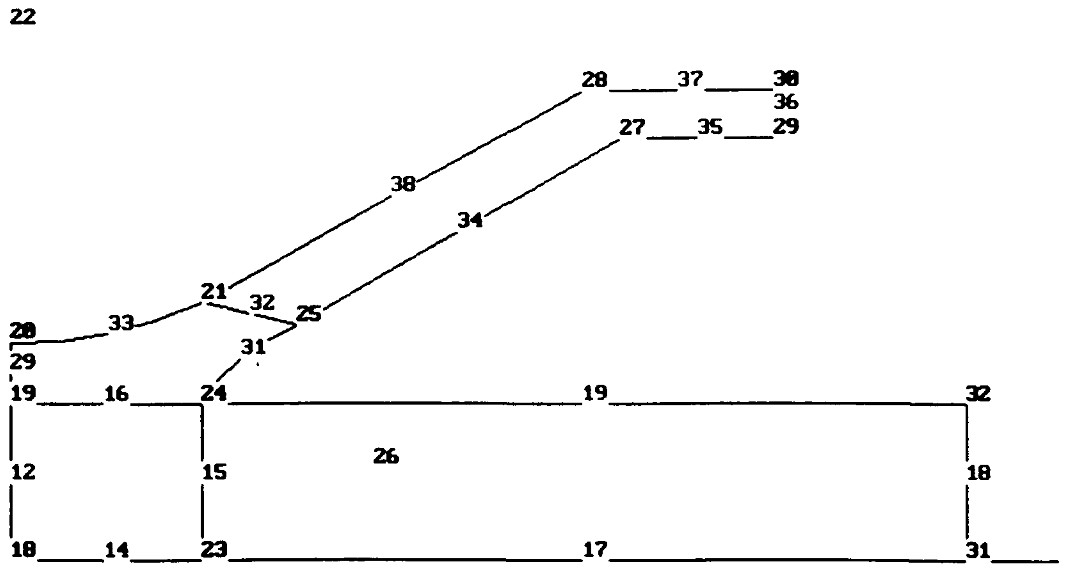
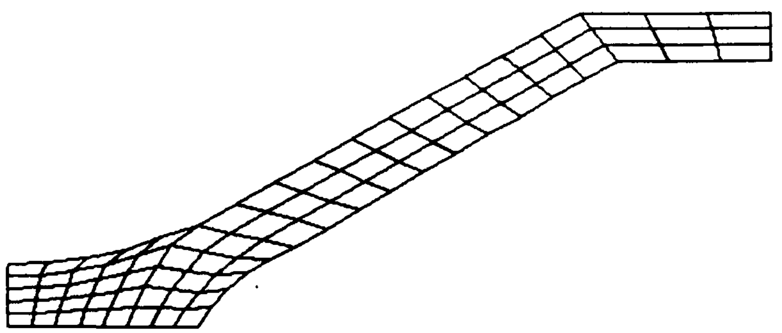


Figure 3.6
Front Scoop Region Grid



4. DETAILS OF THE MESH GENERATION PROCESS

For each sub-area mesh command, the mesh generation process begins by identifying the line or spline which connects the first two points in the command line. Since the line or spline could have been defined in the opposite direction, a test is performed on each line to see if it is reversed. If the two points define a spline, each line in the spline is identified as well. The meshing process begins by subdividing all the edge lines or splines according to the number of divisions in the line definitions. Several scratch files are also maintained to keep track of the line division node numbers for future reference, particularly when merging adjacent areas. The nodes defined on the first line of the area are then swept across the width of the area based on the division spacing of the line or spline between the second and third points. This where the algorithm uses either technique 1 or 2 when generating the grid. If technique 1 is used, the nodes sweep straight across to the opposite side. With technique 2, the curvature of the second side adjusts the node spacing as they sweep across. Within each sub-area all elements are connected by adjacent nodes according to the number of divisions on the perpendicular sides, but adjacent areas are not yet connected. Following completion of the meshing of all sub-areas, the operator can merge perimeter nodes, so that a solid structure is created. Merging is accomplished by cycling through all sub-areas to identify those which happened to have common boundary lines. Scratch files, created previously, contain the edge nodes for each line. The merge routine selects the lowest node number and makes it common to all elements connecting at that location. After merging, some node numbers will no longer be in use. The operator can then select the compress command, which will identify all un-used nodes in the node array. Un-used nodes are then re-assigned to elements having higher node definitions. This command is useful in ensuring that the size of the stiffness matrix is minimized in the finite element analysis. Figure 4.1 shows a close-up of the point and line plot of the left end of the example structure. Figure 4.2 shows the node and element definitions at the vertical sub-area boundary. At this boundary, the nodes have been merged so that the elements are structurally connected.

Figure 4.1
Close-Up of the Left End of the Example Structure

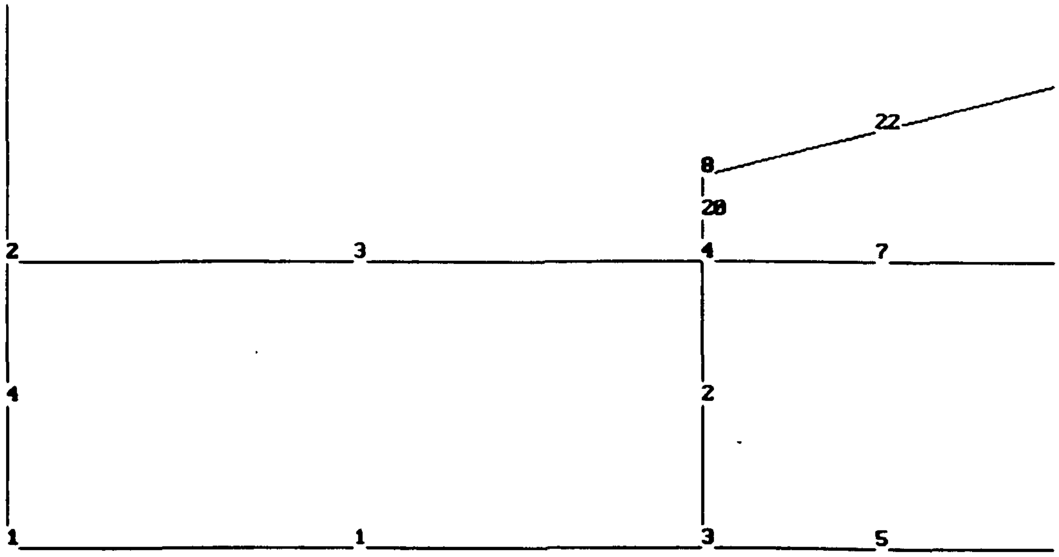
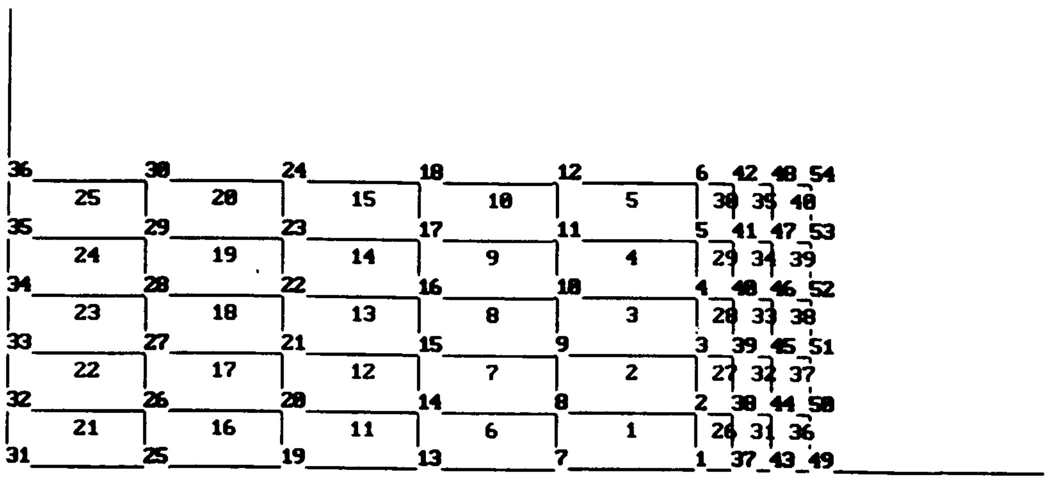


Figure 4.2
Merged Node and Element Plot at the Sub-Area Boundary



APPENDIX A
EXAMPLE INPUT AND OUTPUT

A.1 -- INPUT FILE
A.2 -- NODE FILE OUTPUT
A.3 -- ELEMENT FILE OUTPUT

A.1 -- INPUT FILE

```
P,1,0,0.0
P,2,0,0.5
P,3,2.0,0.0
P,4,2.0,0.5
P,5,4.25,0.0
P,6,4.25,0.5
P,7,4.25,1.0
P,8,2.0,0.65
P,9,5.75,0.0
P,10,5.75,0.5
P,11,4.5,1.25
P,12,4.0443,1.4557
P,13,4.5,1.5
P,14,5.5,1.5
P,15,5.9557,1.4557
P,16,5.5,1.25
P,17,5.75,1.0
P,18,8.0,0.0
P,19,8.0,0.5
P,20,8.0,0.7
P,21,8.5,0.825
P,22,8.0000,1.7
P,23,8.5,0.0
P,24,8.5,0.5
P,25,8.75,0.75
P,26,8.9557,0.2943
P,27,9.6,1.35
P,28,9.5,1.5
P,29,10.0,1.35
P,30,10.0,1.5
P,31,10.5,0.0
P,32,10.5,0.5
L,1,1,3,5,,
L,2,3,4,5,,
L,3,4,2,5,,
L,4,1,2,5,,
L,5,3,5,20,,
L,6,5,6,5,,
L,7,6,4,20,,
L,8,5,9,20,,
L,9,9,10,5,,
L,10,10,6,20,,
L,11,9,18,20,,
L,12,18,19,5,,
L,13,19,10,20,,
L,14,18,23,8,,
L,15,23,24,5,,
L,16,24,19,8,,
L,17,23,31,4,,
L,18,31,32,5,,
L,19,32,24,4,,
L,20,4,8,5,,
L,21,6,7,5,,
L,22,7,8,20,,
L,23,7,11,4,12
L,24,11,13,3,,
L,25,13,14,20,,
L,26,14,16,3,,
L,27,16,17,4,15
L,28,10,17,5,,
L,29,19,20,5,,
L,30,20,17,20,,
L,31,24,25,5,26
L,32,25,21,3,,
L,33,21,20,5,22
L,34,25,27,10,,
L,35,27,29,3,,
L,36,29,30,3,,
L,37,30,28,3,,
L,38,28,21,10,,
S,1,21,23,24,,,
S,2,28,27,26,,,
S,3,32,33,,,,
S,4,34,35,,,,
S,5,37,38,,,,
A,1,3,4,2,1,1,1
A,2,3,4,6,5,1,1
A,3,5,9,10,6,1,1
A,4,9,18,19,10,1,1
A,5,18,23,24,19,1,1
A,6,23,31,32,24,1,1
A,7,4,6,7,8,1,2
A,8,6,10,14,13,1,2
A,9,10,19,20,17,1,2
A,10,20,25,24,19,2,2
A,11,29,30,21,25,1,2
*
```

A.2 -- NODE FILE OUTPUT

1	2.00000	0.000000
2	2.00000	0.100000
3	2.00000	0.200000
4	2.00000	0.300000
5	2.00000	0.400000
6	2.00000	0.500000
7	1.60000	0.000000
8	1.60000	0.100000
9	1.60000	0.200000
10	1.60000	0.300000
11	1.60000	0.400000
12	1.60000	0.500000
13	1.20000	0.000000
14	1.20000	0.100000
15	1.20000	0.200000
16	1.20000	0.300000
17	1.20000	0.400000
18	1.20000	0.500000
19	0.800000	0.000000
20	0.800000	0.100000
21	0.800000	0.200000
22	0.800000	0.300000
23	0.800000	0.400000
24	0.800000	0.500000
25	0.400000	0.000000
26	0.400000	0.100000
27	0.400000	0.200000
28	0.400000	0.300000
29	0.400000	0.400000
30	0.400000	0.500000
31	0.000000	0.000000
32	0.000000	0.100000
33	0.000000	0.200000
34	0.000000	0.300000
35	0.000000	0.400000
36	0.000000	0.500000
37	2.00000	0.000000
38	2.00000	0.100000
39	2.00000	0.200000
40	2.00000	0.300000
41	2.00000	0.400000
42	2.00000	0.500000
43	2.11250	0.000000
44	2.11250	0.100000
45	2.11250	0.200000
46	2.11250	0.300000
47	2.11250	0.400000
48	2.11250	0.500000
49	2.22500	0.000000
50	2.22500	0.100000
51	2.22500	0.200000
52	2.22500	0.300000
53	2.22500	0.400000
54	2.22500	0.500000
55	2.33750	0.000000
56	2.33750	0.100000
57	2.33750	0.200000
58	2.33750	0.300000
59	2.33750	0.400000
60	2.33750	0.500000
61	2.45000	0.000000
62	2.45000	0.100000
63	2.45000	0.200000
64	2.45000	0.300000
65	2.45000	0.400000
66	2.45000	0.500000
67	2.56250	0.000000
68	2.56250	0.100000
69	2.56250	0.200000
70	2.56250	0.300000
71	2.56250	0.400000
72	2.56250	0.500000
73	2.67500	0.000000
74	2.67500	0.100000
75	2.67500	0.200000
76	2.67500	0.300000
77	2.67500	0.400000
78	2.67500	0.500000
79	2.78750	0.000000
80	2.78750	0.100000
81	2.78750	0.200000
82	2.78750	0.300000
83	2.78750	0.400000
84	2.78750	0.500000
85	2.90000	0.000000
86	2.90000	0.100000
87	2.90000	0.200000
88	2.90000	0.300000
89	2.90000	0.400000
90	2.90000	0.500000
91	3.01250	0.000000
92	3.01250	0.100000
93	3.01250	0.200000
94	3.01250	0.300000
95	3.01250	0.400000
96	3.01250	0.500000
97	3.12500	0.000000
98	3.12500	0.100000
99	3.12500	0.200000
100	3.12500	0.300000
101	3.12500	0.400000
102	3.12500	0.500000
103	3.23750	0.000000
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167	4.55000	0.000000
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178	5.37500	0.000000
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183	5.75000	0.000000
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193	4.92500	0.100000
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252	4.62500	0.400000
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254	4.77500	0.400000
255	4.85000	0.400000
256	4.92500	0.400000
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291	5.97500	0.000000
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506	2.78750	0.500000
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513	3.57500	0.500000
514	3.68750	0.500000
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522	2.22500	0.537000
523	2.33750	0.540500
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525	2.56250	0.547500
526	2.67500	0.551000
527	2.78750	0.554500
528	2.90000	0.558000
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531	3.23750	0.568500
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546	2.56250	0.595000
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556	3.68750	0.665000
557	3.80000	0.672000
558	3.91250	0.679000

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563	2.11250	0.600500
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565	2.33750	0.621500
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567	2.56250	0.642500
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571	3.01250	0.684500
572	3.12500	0.695000
573	3.23750	0.705500
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575	3.46250	0.726500
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630	4.62500	0.500000
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632	4.77500	0.500000
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651	4.62500	0.600000
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653	4.77500	0.600000
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735	4.62500	0.999999
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930	6.98750	0.567000

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808	984	985	1006	1005	2
809	985	986	1007	1006	2
810	986	987	1008	1007	2
811	987	988	1009	1008	2
812	988	989	1010	1009	2
813	989	990	1011	1010	2
814	990	991	1012	1011	2
815	991	992	1013	1012	2
816	992	993	1014	1013	2
817	993	994	1015	1014	2
818	994	995	1016	1015	2
819	995	996	1017	1016	2
820	996	997	1018	1017	2
821	997	998	1019	1018	2
822	998	999	1020	1019	2
823	999	1000	1021	1020	2
824	1000	1001	1022	1021	2
825	1001	1002	1023	1022	2
826	1024	1025	1034	1033	2
827	1025	1026	1035	1034	2
828	1026	1027	1036	1035	2
829	1027	1028	1037	1036	2
830	1028	1029	1038	1037	2
831	1029	1030	1039	1038	2
832	1030	1031	1040	1039	2
833	1031	1032	1041	1040	2
834	1033	1034	1043	1042	2
835	1034	1035	1044	1043	2
836	1035	1036	1045	1044	2
837	1036	1037	1046	1045	2

838	1037	1038	1047	1046	2
839	1038	1039	1048	1047	2
840	1039	1040	1049	1048	2
841	1040	1041	1050	1049	2
842	1042	1043	1052	1051	2
843	1043	1044	1053	1052	2
844	1044	1045	1054	1053	2
845	1045	1046	1055	1054	2
846	1046	1047	1056	1055	2
847	1047	1048	1057	1056	2
848	1048	1049	1058	1057	2
849	1049	1050	1059	1058	2
850	1051	1052	1061	1060	2
851	1052	1053	1062	1061	2
852	1053	1054	1063	1062	2
853	1054	1055	1064	1063	2
854	1055	1056	1065	1064	2
855	1056	1057	1066	1065	2
856	1057	1058	1067	1066	2
857	1058	1059	1068	1067	2
858	1060	1061	1070	1069	2
859	1061	1062	1071	1070	2
860	1062	1063	1072	1071	2
861	1063	1064	1073	1072	2
862	1064	1065	1074	1073	2
863	1065	1066	1075	1074	2
864	1066	1067	1076	1075	2
865	1067	1068	1077	1076	2
866	1078	1079	1083	1082	2
867	1079	1080	1084	1083	2
868	1080	1081	1085	1084	2
869	1082	1083	1087	1086	2
870	1083	1084	1088	1087	2
871	1084	1085	1089	1088	2
872	1086	1087	1091	1090	2
873	1087	1088	1092	1091	2
874	1088	1089	1093	1092	2
875	1090	1091	1095	1094	2
876	1091	1092	1096	1095	2
877	1092	1093	1097	1096	2
878	1094	1095	1099	1098	2
879	1095	1096	1100	1099	2
880	1096	1097	1101	1100	2
881	1098	1099	1103	1102	2
882	1099	1100	1104	1103	2
883	1100	1101	1105	1104	2
884	1102	1103	1107	1106	2
885	1103	1104	1108	1107	2
886	1104	1105	1109	1108	2
887	1106	1107	1111	1110	2
888	1107	1108	1112	1111	2
889	1108	1109	1113	1112	2
890	1110	1111	1115	1114	2
891	1111	1112	1116	1115	2
892	1112	1113	1117	1116	2
893	1114	1115	1119	1118	2
894	1115	1116	1120	1119	2
895	1116	1117	1121	1120	2
896	1118	1119	1123	1122	2
897	1119	1120	1124	1123	2
898	1120	1121	1125	1124	2
899	1122	1123	1127	1126	2
900	1123	1124	1128	1127	2
901	1124	1125	1129	1128	2
902	1126	1127	1131	1130	2
903	1127	1128	1132	1131	2
904	1128	1129	1133	1132	2

APPENDIX B
MESH GENERATOR FORTRAN LISTING

```
C       MESH GENERATOR -- AUTOMATIC MESH GENERATION FOR FILE
C       'MESH.IN' -- MESHES ALL AREAS IN THE FILE
C
C       IN THIS CODE 'X' COORDINATES ARE THE 'Z' AXIS
C       ............ 'Y' COORDINATES ARE THE 'R' AXIS
C
        CHARACTER*1 RIN
        DIMENSION ME(8)
C
1       WRITE (*,*)
        WRITE (*,*) 'CHOOSE:'
        WRITE (*,*) '1 - MESH NEW "MESH.IN" FILE'
        WRITE (*,*) '2 - MERGE PERIMETER NODES'
        WRITE (*,*) '3 - CONDENSE OUT UNUSED NODE NUMBERS'
        WRITE (*,*) '4 - (NOT USED)'
        WRITE (*,*) '5 - END (WRITE OUTPUT FILES)'
        WRITE (*,*) '  - INCLUDING F.E. COMPATIBLE INPUT FILE'
        WRITE (*,*)
        READ (*,*) ICHOICE
        WRITE (*,*)
        IF (ICHOICE.EQ.2) GO TO 1500
        IF (ICHOICE.EQ.3) GO TO 2500
        IF (ICHOICE.EQ.4) GO TO 3000
        IF (ICHOICE.EQ.5) GO TO 4000
        OPEN (1,FILE='MESH.IN',STATUS="OLD", FORM="FORMATTED",
     *  RECL=1)
C
C       READ ENTIRE INPUT FILE AND CREATE A FORMATTED SCRATCH FILE
C       POINTS
        OPEN (4,FILE='INPUT',ACCESS="DIRECT",FORM="FORMATTED",
     *  RECL=80,STATUS="NEW")
        OPEN (7,FILE='PLOT.IN',STATUS="NEW")
        NUMP=0
7       FORMAT (1X,I12,F15.6,F15.6)
8       FORMAT (1X,5(I12),I5)
        NUML=0
        NUMS=0
        NUMA=0
C       FIND ALL POINTS
20      FORMAT (A1,I5,F15.6,F15.6)
10      READ (1,*) RIN
        IF (RIN.EQ.'*') GO TO 30
        IF (RIN.NE.'P') GO TO 10
        WRITE (*,*) RIN
        BACKSPACE (1)
        X=0.0
        Y=0.0
        N=0
        READ (1,*) RIN,N,X,Y
        WRITE (*,*) RIN,N,X,Y
        IF (N.GT.NUMP) NUMP=N
        WRITE (4,20,REC=N) RIN,N,X,Y
        GO TO 10
C       FIND ALL LINES
30      REWIND (1)
40      FORMAT (A1,5(I5))
41      FORMAT (A1,7(I5))
45      READ (1,*) RIN
        IF (RIN.EQ.'*') GO TO 50
        IF (RIN.NE.'L') GO TO 45
        WRITE (*,*) RIN
        BACKSPACE (1)
        N=0
        IC=0
        READ (1,*) RIN,N,I1,I2,ND,IC
        WRITE (*,*) RIN,N,I1,I2,ND,IC
        IF (N.GT.NUML) NUML=N
        IREC=NUMP+N
        WRITE (4,40,REC=IREC) RIN,N,I1,I2,ND,IC
        GO TO 45
C       FIND ALL SPLINES
50      REWIND (1)
60      FORMAT (A1,6(I5))
65      READ (1,*) RIN
        IF (RIN.EQ.'*') GO TO 70
        IF (RIN.NE.'S') GO TO 65
        WRITE (*,*) RIN
        BACKSPACE (1)
        N=0
        L1=0
        L2=0
        L3=0
        L4=0
        L5=0
        READ (1,*) RIN,N,L1,L2,L3,L4,L5
        WRITE (*,*) RIN,N,L1,L2,L3,L4,L5
        IF (N.GT.NUMS) NUMS=N
        IREC=NUMP+NUML+N
        WRITE (4,60,REC=IREC) RIN,N,L1,L2,L3,L4,L5
        GO TO 65
C       READ ALL AREAS
70      REWIND (1)
75      READ (1,*) RIN
```

```
      IF (RIN.EQ.'*') GO TO 150
      IF (RIN.NE.'A') GO TO 75
      WRITE (*,*) RIN
      BACKSPACE (1)
      N=0
      J1=0
      J2=0
      J3=0
      J4=0
      READ (1,*) RIN,N,J1,J2,J3,J4,MTYPE,NMATERIAL
      WRITE (*,*) RIN,N,J1,J2,J3,J4,MTYPE,NMATERIAL
      IF (N.GT.NUMA) NUMA=N
      IREC=NUMP+NUML+NUMS+N
      WRITE (4,41,REC=IREC) RIN,N,J1,J2,J3,J4,MTYPE,NMATERIAL
      GO TO 75
C
C     WRITE A POINT AND LINE PLOT INPUT FILE FOR MESHPLOT
151   FORMAT (A1,I12,F15.6,F15.6,I9,I9)
150   WRITE (7,*) 'N',NUMP,NUML,0,0,0
      DO 155 I=1,NUMP
      IREC=I
      READ (4,20,REC=IREC) RIN,N,X,Y
      WRITE (7,151) RIN,N,X,Y,0,0
155   CONTINUE
      DO 160 I=1,NUML
      IREC=NUMP+I
      READ (4,40,REC=IREC) RIN,N,I1,I2,I3,I4
      WRITE (7,*) RIN,N,I1,I2,I3,I4
160   CONTINUE
C     DO 165 I=1,NUMS
C     IREC=NUMP+NUML+I
C     READ (4,60,REC=IREC) RIN,N,L1,L2,L3,L4,L5
C     WRITE (7,*) RIN,N,L1,L2,L3,L4,L5
C165    CONTINUE
C     DO 170 I=1,NUMA
C     IREC=NUMP+NUML+NUMS+I
C     READ (4,41,REC=IREC) RIN,N,J1,J2,J3,J4,IM,NM
C     WRITE (7,*) RIN,N,J1,J2,J3,J4
C170    CONTINUE
      CLOSE (7)
C     STARTING NODE NUMBER
      IN=0
      CLOSE (1)
      OPEN (1,FILE='MERGE',ACCESS="DIRECT",FORM="FORMATTED",
     * RECL=5,STATUS="NEW")
      OPEN (2,FILE='NODESL',ACCESS="DIRECT",FORM="FORMATTED",
     * RECL=43,STATUS="NEW")
C     STARTING ELEMENT NUMBER
      IE=0
      OPEN (3,FILE='ELEML',ACCESS="DIRECT",FORM="FORMATTED",
     * RECL=66,STATUS="NEW")
C
      DO 1000 IA=1,NUMA
      IREC=NUMP+NUML+NUMS+IA
      N=0
      JP1=0
      JP2=0
      JP3=0
      JP4=0
      MTYPE=0
      READ (4,41,REC=IREC) RIN,N,JP1,JP2,JP3,JP4,MTYPE,NMAT
      IF (N.EQ.0) GO TO 1000
      WRITE (*,*) RIN,N,JP1,JP2,JP3,JP4,MTYPE,NMAT
      ND1=0
      ND2=0
C
      WRITE (*,*) 'CALL EDGEMESH K=1'
C     FIND AND MESH LINE, RADIUS, OR SPLINE CONNECTING JP1 TO JP2
      CALL EDGEMESH (1,JP1,JP2,ND1,ND2,IN,NUMP,NUML,NUMS)
      WRITE (*,*) 'CALL EDGEMESH K=2'
C     FIND AND MESH LINE, RADIUS, OR SPLINE CONNECTING JP2 TO JP3
      CALL EDGEMESH (2,JP2,JP3,ND1,ND2,IN,NUMP,NUML,NUMS)
C     FIND AND MESH LINE, RADIUS, OR SPLINE CONNECTING JP3 TO JP4
      CALL EDGEMESH (3,JP4,JP3,ND1,ND2,IN,NUMP,NUML,NUMS)
C     FIND AND MESH LINE, RADIUS, OR SPLINE CONNECTING JP4 TO JP1
      CALL EDGEMESH (4,JP1,JP4,ND1,ND2,IN,NUMP,NUML,NUMS)
C
C     ASSIGN NODES TO ELEMENTS FOR THIS AREA
C
      DO 250 KE=1,ND2
      DO 200 JE=1,ND1
      IE=IE+1
      N1=IN+JE+((ND1+1)*(KE-1))
      N2=N1+1
      N3=N2+ND1+1
      N4=N3-1
      WRITE (3,8,REC=IE) IE,N1,N2,N3,N4,NMAT
200   CONTINUE
250   CONTINUE
C
C     FIND X,Y COORDINATES FOR INTERIOR NODES FOR THIS AREA
C
      NN=IN+1+ND1+1
```

```
      DO 400 I=1,(ND2-1)
      NE1=IN+1+ND1+(1+ND1)*I
      NS1=NE1-ND1
      READ (2,7,REC=NE1) NX,XE1,YE1
      WRITE (*,*) NX,XE1,YE1
      READ (2,7,REC=NS1) NX,XS1,YS1
      DX=(XE1-XS1)/ND1
      DO 300 J=1,(ND1-1)
      IF (MTYPE.EQ.2) THEN
      NE2=IN+(ND1+1)*(ND2+1)-ND1+J
      NS2=IN+1+J
      READ (2,7,REC=NE2) NY,XE2,YE2
      READ (2,7,REC=NS2) NY,XS2,YS2
      DY=(YE2-YS2)/ND2
      Y=YS2+DY*I
      ENDIF
      IF (MTYPE.EQ.1) THEN
      DY=(YE1-YS1)/ND1
      Y=YS1+DY*J
      ENDIF
      NN=NN+1
      X=XS1+DX*J
      WRITE (2,7,REC=NN) NN,X,Y
300   CONTINUE
      NN=NN+2
400   CONTINUE
      IN=IN+(ND1+1)*(ND2+1)
1000  CONTINUE
1001  FORMAT (I5)
      WRITE (1,1001) 0
      CLOSE (1)
      CLOSE (2)
      CLOSE (3)
      CLOSE (4)
      CLOSE (5)
      CLOSE (6)
      OPEN (1,FILE='TOTALS',STATUS="NEW")
      WRITE (1,*) IN,IE
      CLOSE (1)
      GO TO 1
C
C     MERGE NODES ROUTINE
1500  OPEN (1,FILE='TOTALS')
      READ (1,*) IN,IE
      CLOSE (1)
      OPEN (2,FILE='NODESL',ACCESS="DIRECT",FORM="FORMATTED",
     * RECL=43)
      OPEN (3,FILE='ELEML',ACCESS="DIRECT",FORM="FORMATTED",
     * RECL=66)
      OPEN (4,FILE='MERGE',ACCESS="DIRECT",FORM="FORMATTED",
     * RECL=5)
C     CREATE A NODE-ELEMENT FILE
      OPEN (5,FILE='NOEL',ACCESS="DIRECT",FORM="FORMATTED",
     * RECL=45)
1510  FORMAT (9(I5))
      CALL NOEL (IN,IE)
C
C     MERGE OUT NODES ON COMMON PERIMETER LINES
C
1610  FORMAT (A2)
1611  FORMAT (I5)
      JREC=1
1615  KREC=JREC
      READ (4,1611,REC=KREC) ISTAR
      WRITE (*,*) 'ISTAR',ISTAR
      IF (ISTAR.EQ.0) GO TO 2400
      READ (4,1611,REC=KREC) L1
      WRITE (*,*) 'L1=',L1
      KREC=KREC+1
      READ (4,1611,REC=KREC) NNL1
      KREC=KREC+NNL1+1
      JREC=KREC
      IF (L1.EQ.-1) GO TO 1615
C     FIND IF LINE L1 REPEATS IN THIS FILE AND MERGE OUT NODES
1620  READ (4,1611,REC=KREC) ISTAR
      WRITE (*,*) 'ISTAR',ISTAR
      IF (ISTAR.EQ.0) GO TO 1615
      READ (4,1611,REC=KREC) L2
      WRITE (*,*) 'L2=',L2
      MREC=KREC
      KREC=KREC+1
      READ (4,1611,REC=KREC) NNL2
      IF (L1.NE.L2) GO TO 1650
C     WE HAVE A MATCH
      KREC=KREC+1
      WRITE (4,1611,REC=MREC) -1
C     REPLACE L2 NODES WITH L1 NODES IN ELEMENT-NODE FILE 'ELEML'
      LREC1=JREC-NNL1
      DO 1625 I=1,NNL1
      READ (4,1611,REC=LREC1) N1
      READ (4,1611,REC=KREC) N2
      LREC1=LREC1+1
      KREC=KREC+1
```

```
      WRITE (*,*) N1,N2
      READ (5,1510,REC=N2) JN2,ME(1),ME(2),ME(3),ME(4),ME(5),ME(6),
     * ME(7),ME(8)
      DO 1624 J=1,8
      IF (ME(J).EQ.0) GO TO 1624
      NREC=ME(J)
      READ (3,8,REC=NREC) N,J1,J2,J3,J4,NMAT
      IF (N2.EQ.J1) WRITE (3,8,REC=NREC) N,N1,J2,J3,J4,NMAT
      IF (N2.EQ.J2) WRITE (3,8,REC=NREC) N,J1,N1,J3,J4,NMAT
      IF (N2.EQ.J3) WRITE (3,8,REC=NREC) N,J1,J2,N1,J4,NMAT
      IF (N2.EQ.J4) WRITE (3,8,REC=NREC) N,J1,J2,J3,N1,NMAT
C     REPLACE N2 WITH 0 IN 'NODESL' FILE
      WRITE (2,7,REC=N2) 0,0,0
1624  CONTINUE
1625  CONTINUE
      GO TO 1620
1650  KREC=KREC+NNL2+1
1660  GO TO 1620
2400  CONTINUE
C     FINISHED
      CLOSE (2)
      CLOSE (3)
      CLOSE (4)
      CLOSE (5)
      GO TO 1
C
C     CONDENSE NODE NUMBERS ROUTINE
2500  OPEN (1,FILE='TOTALS')
      READ (1,*) IN,IE
      OPEN (2,FILE='NODESL',ACCESS="DIRECT",FORM="FORMATTED",
     * RECL=43)
      OPEN (3,FILE='ELEML',ACCESS="DIRECT",FORM="FORMATTED",
     * RECL=66)
      OPEN (5,FILE='NOEL',ACCESS="DIRECT",FORM="FORMATTED",
     * RECL=45)
      CALL NOEL (IN,IE)
      ID=0
      DO 2600 IR=1,IN
      READ (2,7,REC=IR) N,X,Y
      WRITE (*,*) N,X,Y
      IF (N.EQ.0) ID=ID+1
      IF (N.EQ.0) GO TO 2600
      IF (ID.EQ.0) GO TO 2600
      IW=IR-ID
      READ (5,1510,REC=IR) JN2,ME(1),ME(2),ME(3),ME(4),ME(5),ME(6),
     * ME(7),ME(8)
      N=IR-ID
      WRITE (2,7,REC=IW) N,X,Y
      WRITE (2,7,REC=IR) 0,0,0
      DO 2550 J=1,8
      IF (ME(J).EQ.0) GO TO 2550
      NREC=ME(J)
      READ (3,8,REC=NREC) JE,J1,J2,J3,J4,JMAT
      IF (IR.EQ.J1) WRITE (3,8,REC=NREC) JE,N,J2,J3,J4,JMAT
      IF (IR.EQ.J2) WRITE (3,8,REC=NREC) JE,J1,N,J3,J4,JMAT
      IF (IR.EQ.J3) WRITE (3,8,REC=NREC) JE,J1,J2,N,J4,JMAT
      IF (IR.EQ.J4) WRITE (3,8,REC=NREC) JE,J1,J2,J3,N,JMAT
2550  CONTINUE
2600  CONTINUE
      IN=IN-ID
      REWIND (1)
      WRITE (1,*) IN,IE
      CLOSE (1)
      CLOSE (2)
      CLOSE (3)
      CLOSE (5)
      GO TO 1
C
C     RENUMBER NODES, AND ELEMENTS (BANDWIDTH) ROUTINE
3000  CONTINUE
      GO TO 1
C
C     WRITE OUTPUTFILES COMPATIBLE WITH MESHPLOT
4000  OPEN (5,FILE='NODES',STATUS="NEW")
      OPEN (6,FILE='ELEMENTS',STATUS="NEW")
      OPEN (2,FILE='NODESL',ACCESS="DIRECT",FORM="FORMATTED",
     * RECL=43)
      OPEN (3,FILE='ELEML',ACCESS="DIRECT",FORM="FORMATTED",
     * RECL=66)
      OPEN (4,FILE='FE.IN')
4001  FORMAT (' ET,1,42,0,0,1')
4002  FORMAT (' EX,',I3,',')
4003  FORMAT (' NUXY,',I3,',')
4004  FORMAT (' DENS,',I3,',')
4005  FORMAT (' MAT,',I3)
      OPEN (1,FILE='TOTALS')
      READ (1,*) IN,IE
      CLOSE (1)
      DO 4010 I=1,IN
      READ (2,7,REC=I) N,X,Y
      WRITE (5,*) ' ',N,X,Y
C     F.E. USES Y=Z AND X=R
      WRITE (4,*) ' N,',N,',',Y,',',X
```

```
4010    CONTINUE
        WRITE (4,4001)
        NNMAT=0
        DO 4020 I=1,IE
        READ (3,8,REC=I) N,N1,N2,N3,N4,NMAT
        WRITE (6,*) ' ',N,N1,N2,N3,N4,NMAT
        IF (NMAT.EQ.NNMAT) GO TO 4015
        NNMAT=NMAT
        WRITE (4,4002) NNMAT
        WRITE (4,4003) NNMAT
        WRITE (4,4004) NNMAT
        WRITE (4,4005) NNMAT
4015    WRITE (4,*) ' E,',N1,',',N2,',',N3,',',N4
4020    CONTINUE

5000    END

        SUBROUTINE NOEL (IN,IE)
1       FORMAT (9(I5))
2       FORMAT (1X,5(I12),I5)
        DO 10 I=1,IN
10      WRITE (5,1,REC=I) I,0,0,0,0,0,0,0,0
        DO 20 I=1,IE
        READ (3,2,REC=I) N,N1,N2,N3,N4,NMAT
        CALL ENTER (N1,I)
        CALL ENTER (N2,I)
        CALL ENTER (N3,I)
        CALL ENTER (N4,I)
20      CONTINUE
        RETURN
        END

        SUBROUTINE ENTER (K,J)
1       FORMAT (9(I5))
        READ (5,1,REC=K) I,M1,M2,M3,M4,M5,M6,M7,M8
        IF (M1.EQ.0) WRITE (5,1,REC=K) I,J,M2,M3,M4,M5,M6,M7,M8
        IF (M1.EQ.0) GO TO 10
        IF (M2.EQ.0) WRITE (5,1,REC=K) I,M1,J,M3,M4,M5,M6,M7,M8
        IF (M2.EQ.0) GO TO 10
        IF (M3.EQ.0) WRITE (5,1,REC=K) I,M1,M2,J,M4,M5,M6,M7,M8
        IF (M3.EQ.0) GO TO 10
        IF (M4.EQ.0) WRITE (5,1,REC=K) I,M1,M2,M3,J,M5,M6,M7,M8
        IF (M4.EQ.0) GO TO 10
        IF (M5.EQ.0) WRITE (5,1,REC=K) I,M1,M2,M3,M4,J,M6,M7,M8
        IF (M5.EQ.0) GO TO 10
        IF (M6.EQ.0) WRITE (5,1,REC=K) I,M1,M2,M3,M4,M5,J,M7,M8
        IF (M6.EQ.0) GO TO 10
        IF (M7.EQ.0) WRITE (5,1,REC=K) I,M1,M2,M3,M4,M5,M6,J,M8
        IF (M7.EQ.0) GO TO 10
        IF (M8.EQ.0) WRITE (5,1,REC=K) I,M1,M2,M3,M4,M5,M6,M7,J
10      RETURN
        END

        SUBROUTINE EDGEMESH (K,JJ1,JJ2,ND1,ND2,IIN,NUMP,NUML,NUMS)
C       'K' = EDGE NUMBER; 'IIN' = ENDING NODE NUMBER OF LAST AREA
        CHARACTER*1 RIN
        DIMENSION L(5),IP1(5),IP2(5),IND(5),IC(5)

1       FORMAT (I5)
2       FORMAT (A1,I5,F15.6,F15.6)
3       FORMAT (A1)
4       FORMAT (A1,5(I5))
6       FORMAT (A1,6(I5))
        GO TO 20
C
C       LOOK FOR A SPLINE CONNECTING JJ1 AND JJ2
C
7       IF (NUMS.EQ.0) GO TO 100
        IREC=NUMP+NUML
10      IREC=IREC+1
        IF (IREC.GT.(NUMP+NUML+NUMS)) GO TO 100
        ICHECK=0
        READ (4,6,REC=IREC) RIN,N,L(1),L(2),L(3),L(4),L(5)
        WRITE (*,*) RIN,N,L(1),L(2),L(3),L(4),L(5)
        JF=5
        IF (L(2).EQ.0) GO TO 10
        IF (L(5).EQ.0) JF=4
        IF (L(4).EQ.0) JF=3
        IF (L(3).EQ.0) JF=2
16      JREC=NUMP+L(1)
        READ (4,4,REC=JREC) RIN,L(1),IP1(1),IP2(1),IND(1),IC(1)
        WRITE (*,*) RIN,L(1),IP1(1),IP2(1),IND(1),IC(1)
        IF (IP2(1).EQ.JJ1) THEN
        IRP=IP1(1)
        IP1(1)=IP2(1)
        IP2(1)=IRP
        ENDIF
        IF (IP1(1).EQ.JJ1) GO TO 17
        IF (ICHECK.EQ.1) GO TO 10
C       REVERSE SPLINE ORDER AND THEN CHECK
        L1=L(5)
        L2=L(4)
        L3=L(3)
```

```
      L4=L(2)
      L5=L(1)
      IF (JF.EQ.5) THEN
      L(1)=L1
      L(2)=L2
      L(3)=L3
      L(4)=L4
      L(5)=L5
      ENDIF
      IF (JF.EQ.4) THEN
      L(1)=L2
      L(2)=L3
      L(3)=L4
      L(4)=L5
      L(5)=L1
      ENDIF
      IF (JF.EQ.3) THEN
      L(1)=L3
      L(2)=L4
      L(3)=L5
      L(4)=L1
      L(5)=L2
      ENDIF
      IF (JF.EQ.2) THEN
      L(1)=L4
      L(2)=L5
      L(3)=L1
      L(4)=L2
      L(5)=L3
      ENDIF
      ICHECK=1
      GO TO 16
17    JREC=NUMP+L(JF)
      READ (4,4,REC=JREC) RIN,L(JF),IP1(JF),IP2(JF),IND(JF),IC(JF)
      WRITE (*,*) RIN,L(JF),IP1(JF),IP2(JF),IND(JF),IC(JF)
      IF (IP1(JF).EQ.JJ2) THEN
      IRP=IP2(JF)
      IP2(JF)=IP1(JF)
      IP1(JF)=IRP
      ENDIF
      IF (IP2(JF).NE.JJ2) GO TO 10
      WRITE (*,*) 'ITS A SPLINE'
C     **** IT'S A SPLINE ****
C     READ THE INTERIOR LINES
      IF (JF.EQ.2) GO TO 13
      DO 12 I=1,JF
      IF (I.EQ.1) GO TO 11
      IF (I.EQ.JF) GO TO 11
      JREC=NUMP+L(I)
      READ (4,4,REC=JREC) RIN,L(I),IP1(I),IP2(I),IND(I),IC(I)
      WRITE (*,*) RIN,L(I),IP1(I),IP2(I),IND(I),IC(I)
      IF (IP1(I).NE.IP2(I-1)) THEN
      IRP=IP1(I)
      IP1(I)=IP2(I)
      IP2(I)=IRP
      ENDIF
11    CONTINUE
12    CONTINUE
13    CONTINUE
      ND=0
      DO 14 I=1,JF
14    ND=ND+IND(I)
      IF (K.EQ.1) THEN
      ND1=ND
      NS=IIN+1
      NIN=1
      ENDIF
      IF (K.EQ.2) THEN
      ND2=ND
      NS=IIN+(1+ND1)
      NIN=1+ND1
      ENDIF
      IF (K.EQ.3) THEN
      NS=IIN+(1+ND1)*ND2+1
      NIN=1
      ENDIF
      IF (K.EQ.4) THEN
      NS=IIN+1
      NIN=1+ND1
      ENDIF
      DO 15 I=1,JF
      WRITE (*,*) 'CALL MESH (SPLINE LINE)'
      WRITE (1,1) L(I)
      WRITE (1,1) IND(I)+1
      CALL MESH (NS,NIN,IP1(I),IP2(I),IND(I),IC(I))
      NS=NS+NIN*IND(I)
15    CONTINUE
      GO TO 100
C
C     LOOK FOR A LINE OR RADIUS
C
20    IREC=NUMP
25    IREC=IREC+1
```

```
      IF (IREC.GT.(NUMP+NUML)) GO TO 7
      READ (4,4,REC=IREC) RIN,N,IP1(1),IP2(1),IND(1),IC(1)
      WRITE (*,*) RIN,N,IP1(1),IP2(1),IND(1),IC(1)
      IF (IP1(1).EQ.JJ2) THEN
      IRP=IP1(1)
      IP1(1)=IP2(1)
      IP2(1)=IRP
      ENDIF
      IF (IP1(1).NE.JJ1) GO TO 25
      IF (IP2(1).NE.JJ2) GO TO 25
      IF (K.EQ.1) THEN
      ND1=IND(1)
      NS=IIN+1
      NIN=1
      ENDIF
      IF (K.EQ.2) THEN
      ND2=IND(1)
      NS=IIN+1+ND1
      NIN=1+ND1
      ENDIF
      IF (K.EQ.3) THEN
      NS=IIN+(1+ND1)*ND2+1
      NIN=1
      ENDIF
      IF (K.EQ.4) THEN
      NS=IIN+1
      NIN=1+ND1
      ENDIF
      WRITE (1,1) N
      WRITE (1,1) IND(1)+1
      WRITE (*,*) 'CALL MESH LINE OR RADIUS'
      CALL MESH (NS,NIN,IP1(1),IP2(1),IND(1),IC(1))
100   RETURN
      END

      SUBROUTINE MESH (NS,NIN,I1,I2,ND,JC)
      CHARACTER*1 RIN
1     FORMAT (A1,I5,F15.6,F15.6)
2     FORMAT (1X,I12,F15.6,F15.6)
3     FORMAT (I5)
      IREC=I1
      READ (4,1,REC=IREC) RIN,N,X1,Y1
      WRITE (*,*) RIN,N,X1,Y1
      IREC=I2
      READ (4,1,REC=IREC) RIN,N,X2,Y2
      IF (JC.NE.0) THEN
      IREC=JC
      READ (4,1,REC=IREC) RIN,N,XC,YC
      ENDIF
      I=NS
      IF (JC.NE.0) GO TO 20
      DX=(X2-X1)/ND
      XS=X1
      DY=(Y2-Y1)/ND
      YS=Y1
      DO 10 J=0,ND
      XI=XS+DX*J
      YI=YS+DY*J
      WRITE (2,2,REC=I) I,XI,YI
      WRITE (1,3) I
      I=I+NIN
10    CONTINUE
      GO TO 100
20    R=((X1-XC)**2+(Y1-YC)**2)**.5
      DX1=ABS(X1-XC)
      DX2=ABS(X2-XC)
      DY1=ABS(Y1-YC)
      DY2=ABS(Y2-YC)
      PI=3.14159
      IF (X1.GT.XC.AND.Y1.GE.YC) T1=ATAN(DY1/DX1)
      IF (X2.GT.XC.AND.Y2.GE.YC) T2=ATAN(DY2/DX2)
      IF (X1.GT.XC.AND.Y1.LT.YC) T1=2.0*PI-ATAN(DY1/DX1)
      IF (X2.GT.XC.AND.Y2.LT.YC) T2=2.0*PI-ATAN(DY2/DX2)
      IF (X1.LT.XC.AND.Y1.GE.YC) T1=PI-ATAN(DY1/DX1)
      IF (X2.LT.XC.AND.Y2.GE.YC) T2=PI-ATAN(DY2/DX2)
      IF (X1.LT.XC.AND.Y1.LT.YC) T1=PI+ATAN(DY1/DX1)
      IF (X2.LT.XC.AND.Y2.LT.YC) T2=PI+ATAN(DY2/DX2)
      IF (X1.EQ.XC.AND.Y1.GT.YC) T1=PI/2.0
      IF (X2.EQ.XC.AND.Y2.GT.YC) T2=PI/2.0
      IF (X1.EQ.XC.AND.Y1.LT.YC) T1=PI+PI/2.0
      IF (X2.EQ.XC.AND.Y2.LT.YC) T2=PI+PI/2.0
      IF (T1.GE.0.0.AND.T1.LE.(PI/2.0).AND.T2.GE.(PI+PI/2.0))
     * T2=2.0*PI-T2
      IF (T2.GE.0.0.AND.T2.LE.(PI/2.0).AND.T1.GE.(PI+PI/2.0))
     * T2=T2+2.0*PI
      DT=(T2-T1)/ND
      DO 30 J=0,ND
      XI=XC+R*COS(T1+J*DT)
      YI=YC+R*SIN(T1+J*DT)
      WRITE (2,2,REC=I) I,XI,YI
      WRITE (1,3) I
      I=I+NIN
30    CONTINUE
100   RETURN
      END
```